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Performance of Stinger Teams Using the RADES Multiple Weapon Configuration

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PERFORMANCE OF STINGER TEAMS USING THE RADES MULTIPLE WEAPON CONFIGURATION

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INTRODUCTION

Realistic, collective training of Short Range Air Defense (SHORAD) and Forward Area Air Defense (FAAD) units is essential for combat readiness. However, the air defense artillery (ADA) community has a limited number of options currently available for pursuit of this requirement. The air defense community must develop its own, requirements-driven, collective training system. The system must provide valid, reliable and realistic training with accurate, immediate feedback. The needed system should provide effective, criterion-referenced training trials, under varying atmospheric conditions, for most days of the year. The system should be sufficiently flexible to allow the training of single fire units, sections, or a platoon. Finally, the training system should not burden the air defense community with unreasonably high demands for resources (dollars, equipment, personnel, space, and time).

ARI has recently been conducting research in an effort to assess the capability of the Realistic Air Defense Engagement System (RADES) to provide effective training to SHORAD and FAAD units. RADES is a simulation system. SHORAD soldiers, employing their actual weapon systems, engage subscale jet and helicopter aircraft in an outdoor desert environment. The weapons are instrumented, allowing RADES to record gunner actions such as identification friend or foe (IFF) interrogation, acquisition, lock-on, superelevate, and fire. In addition, verbal engagement actions such as detection, visual identification, and engagement or cease engagement commands are recorded. RADES also provides performance outcome measures such as identification accuracy, hit or miss data, and hostile ordnance release prevention.

RADES data-collection capabilities have recently been expanded to include the recording of responses from up to five independent SHORAD fire units simultaneously. These fire units can be homogeneous (e.g., all Stingers) or heterogeneous (e.g., a mix of Stingers and Chaparrals). All fire units engage the same aircraft. The five stations currently available are independent of one another, having no common communications network, and no intervisibility or interaudibility.

The primary purpose of the research discussed in this report was to employ this multiple fire unit capability to collect human performance data from four Stinger teams simultaneously. The second purpose was to demonstrate the utility of RADES as a training tool by showing that teams exercised in RADES improve their performance as a result of practice with feedback. The third purpose was to use RADES to provide collective training to Stinger teams stationed at Fort Bliss, using representative and realistic scenarios.

Data presented within this report should not be considered indicative of the actual technical performance capability of the Stinger missile system itself when employed against the real full-scale aircraft simulated by RADES.

METHOD

RADES is a Short Range Air Defense engagement simulation located in the desert at Condron Field, White Sands Missile Range, New Mexico. Soldiers manning actual instrumented weapon systems engage subscale flying fixed-wing and pop-up rotary-wing aircraft representing US and Soviet designs. Crew engagement actions are recorded in terms of elapsed time and range of aircraft at event occurrence. Time measures are accurate to 250 milliseconds and range measures are accurate to 44 meters subscale (300 meters full-scale). Detailed descriptions of RADES can be found elsewhere (Appendix; Drewfs, Barber, Johnson & Frederickson, 1988; Lockhart, Johnson, & Sanders, 1987). The validity of RADES as a subscale air defense simulation has been established empirically and is discussed in Drewfs et al. (1988) and Johnson, Barber, and Lockhart (1988).

The present experiment investigated the effect of repeated trials with instructional feedback on measures of aircraft engagement response times and ranges for Stinger teams. Due to a small sample size, the statistical test used was the non-parametric sign test. A one-tailed alpha of 0.1 was designated as the criterion for statistical significance in testing the hypothesis that performance in the posttest would be superior to that in the pretest.

Thirty scenarios (trials) were administered to each of nine Stinger teams. Each trial was followed by corrective feedback (target hit or missed, correctness of ID, correctness of team actions). The training scenario treatments were grouped into four sub-experiments. These differed in the type of aircraft stimuli used and the number of aircraft presented. The four sub-experiments are described in Table 1.

Table 1
Training Sub-Experiments

No.	Code*	Description
1	SFW	Single Fixed-Wing Scenarios (Jets)
2	SRW	Single Rotary-Wing Scenarios (Helicopters)
3	SEQMRW	Sequential Multiple Rotary-Wing Scenarios
4	SIMMRW	Simultaneous Multiple Rotary-Wing Scenarios

* Used in Table 2

Each of the four sub-experiments represented a combination of equivalent scenarios and target presentations. Table 2 defines each scenario presented. For purposes of analysis, the double and triple simultaneous rotary-wing scenarios were combined into a single sub-experiment (number 4). Doing this increased the number of cases for 1st and 2nd target engagements, without compromise to 3rd target engagements.

In Table 2, the fixed-wing (FW) scenario patterns labeled 11, 12, and 1 o'clock, refer to the approach azimuth of these target stimuli, relative to the Stinger weapon position. Twelve o'clock azimuth was the team's primary target line (PTL). The team's search sector was 90 degrees, as per doctrine (FM 44-18-1, 1984). In the case of rotary-wing (RW) sub-experiments, the pattern refers to one of six helicopter target stands labeled by the numbers 1 to 6. Stand 1 is the leftmost stand and stand 6 is the rightmost stand, relative to the weapon position. Helicopter target numbering proceeded from left to right in numeric order. Helicopter stands were approximately equal distance from the weapon position, at a constant range of 600 meters (1/5 scale) equating to 3 kilometers (km) full-scale.

Table 2
Stinger Training Scenarios

Scenario		Target/Pattern		Aircraft	Presentation (Code*)	Duration
Set 1	Set 2	Set 1	Set 2			
1	15	11 o'clk	11 o'clk	MiG-27	SFW	N/A
2	16	12 o'clk	12 o'clk	Su-25	SFW	N/A
3	17	1 o'clk	1 o'clk	A-7	SFW	N/A
4	18	12 o'clk	12 o'clk	A-10	SFW	N/A
5	19	6	2	AH-1	SRW	20 Secs
6	20	1	6	UH-1	SRW	20 Secs
7	21	3	3	CH-3	SRW	20 Secs
8	22	5	1	Mi-24	SRW	20 Secs
9	23	2	5	Mi-28	SRW	20 Secs
10	24	4	4	Mi-8	SRW	20 Secs
11	25	4,1	4,2	Mi-8;UH1/AH1	SEQMRW	20 Secs
12	26	3,2	3,5	CH-3; Mi-28	SEQMRW	20 Secs
13	27	5,2	1,5	Mi-24;Mi-28	SIMMRW	40 Secs
14	28	1,3,5	6,3,1	UH-1; CH-3; Mi-24	SIMMRW	40 Secs

NOTE: Set 1 = morning set
Set 2 = afternoon set

* See Table 1

Participating Stinger teams responded to two sets of scenarios: the morning set and the afternoon set. Participants received one FW and one RW practice scenario prior to the initiation of the first set of trials. A set of data-collection trials consisted of fifteen scenarios with two being pretest and two being posttest scenarios. The teams received a set of trials in the morning and an equivalent set in a different order in the afternoon. Teams assumed the same weapon position for both morning and afternoon sets. Time of day (i.e., morning versus afternoon) was a within teams independent variable.

The experimental design was a repeated measures (pre-post) approach. Engagement responses to the first two scenarios and the last two scenarios within each set of data-collection trials were the pre-post measures. Pre-post scenarios consisted of one fixed-wing and one rotary-wing trial each. Pre-post responses were compared within sets (AM or PM). For FW, number 1 was the pre-post scenario in the morning and scenario 16 was the one for the afternoon. For RW, the morning pre-post scenarios were 11 and 12 respectively; in the afternoon they were 25 and 26 respectively. Comparisons were also made for morning versus afternoon trials. For these comparisons, average single FW and single RW responses for each team were used.

Fixed-wing aircraft (1/7 scale) flew at a constant rate of 98 miles per hour. This equates to approximately 600 knots full-scale. Fixed-wing targets consistently maintained an altitude of 15 to 30 meters, approximating a mean full-scale altitude of 160 meters. Fixed-wing aircraft turned into the engagement zone at an equivalent full-scale range of 20 km and came to within 1.5 km of the weapon position prior to turning from the inbound to the outbound flight-path segment.

The order of scenario treatment presentations was randomized, except for the pretest scenarios which were always presented first and second, and the posttest scenarios which were always the last two presented. Table 3 depicts the actual order of presentation. D1 and D2 represent the two practice trials.

Table 3
Scenario Sequence

Day	Set	Sequence
1	am	D1,D2,1,11,3,8,14,9,6,4,7,13,2,5,10,12,1
1	pm	16,25,24,20,21,18,27,23,17,22,15,28,19,26,16
2	am	D1,D2,11,1,10,6,5,4,7,13,9,14,2,8,3,12,1
2	pm	25,16,22,15,28,23,20,19,17,27,21,18,24,16,26
3	am	D1,D2,1,11,6,13,2,5,14,9,10,4,7,3,8,12,1
3	pm	25,16,17,24,20,15,21,28,23,27,22,18,19,26,16
4	am	D1,D2,11,1,9,2,6,8,10,3,13,7,4,5,14,1,12
4	pm	25,16,24,23,22,18,19,20,17,27,28,15,21,26,16

Dependent Measures

The dependent measures recorded in this experiment are listed in Table 4. These task performance measures were a trial-by-trial record of engagement actions, usually in terms of elapsed time or target range. Some task performance measures were aggregated over a group of trials to become summary performance measures. Summary measures included percent targets detected, percent targets identified, percent correct identifications, percent hostiles engaged, percent friends engaged, percent hostiles destroyed, percent fratricide, and percent hostiles releasing ordnance. Ordnance release prevention was derived based on: ordnance delivery time/range, time/range of weapon fire, and elapsed time/range to missile-target intercept. RW ordnance release was designated as 18 seconds from target availability. The FW ordnance release point was designated as four kilometers from the weapon.

With rare exceptions, superelevation immediately preceded fire and command engage/cease engagement immediately followed visual identification. Thus, superelevation and command engage/cease engagement were excluded from further analyses.

It can be noted throughout the presentation of results that sample size (N) varied across different engagement events. This is as it should be. If Stinger teams neglect to perform a particular engagement task then RADES cannot record it. For example, in the "heat of battle" some gunners forget to push the IFF button. Hence, the N for IFF is often lower than that for other events. Or, a gunner may achieve IR lock-on to a target but then receive a command to cease engagement. In this case, no fire event would be recorded. Thus, unequal N for different engagement events is a normal condition in RADES.

Table 4
Dependent Variables

CODE	TITLE/DESCRIPTION	DUTY	INTERPRETATION
IDCOR	Correctness of Identification	TL	Number of correct identifications divided by number of targets identified
RDET	Range of Detection	TL or G	The slant range from the weapon to the target when the event took place; greater ranges usually indicate better performance for detection and identification but not always for the other events (target can be inbound or outbound). Range is relevant for fixed-wing targets only since rotary-wing targets simply pop-up from a static position
RID	Range of Identification	TL	
RENG	Range of Command to Engage	TL	
RACQ	Range of Initial Acquisition	G	
RIFF	Range of Interrogation	G	
RLOCK	Range of Lock-On	G	
RFIRE	Range of Weapon Fire	G	
RKILL	Range of Target at Kill Indication	Both	
TDET	Time of Detection	TL or G	Based on seconds after target availability where availability begins when visual line-of-sight is achieved on the first RW target
TID	Time of Identification	TL	Time interval between Detection and Identification
TENG	Time of Command to Engage	TL	Time interval between Identification and Command to Engage/ Cease Engagement

Table 4 (continued)

TACQ	Time of Initial Acquisition	G	Time interval between Detection and Acquisition
TIFF	Time of Interrogation	G	Time interval between Detection and IFF
TLOCK	Time of Lock-On	G	Time interval between Acquisition and Lock-on
TFIRE	Time of Weapon Fire	G	Time interval between Lock-on and Fire
TKILL	Time of Target at Kill Indication	Both	Time interval between line-of-sight and target destroyed
TTOT	Total Engagement Time	Both	Time interval between Detection and Fire
THAND	Time of Handoff	Both	Time interval between Command to Engage and Weapon Fire

KEY: TL = Team Leader; G = Gunner

Participants

Participants in the present study were nine Stinger teams, consisting of one team leader and one gunner each, from the Stinger Platoon, Headquarters and Headquarters Troop, 3rd Armored Cavalry Regiment, Fort Bliss, Texas. Soldiers' median rank was E4, and ranged from E2 to E5.

The Stinger Missile System

The Stinger is a man-portable, shoulder-fired, infrared-homing (heat seeking) guided missile system. The weapon requires no control from the gunner after firing. Stinger has an identification friend or foe (IFF) subsystem which aids the team chief in identifying friendly aircraft. The Stinger weapon system consists of four components: the weapon round, IFF subsystem, shipping and storage containers, and transport harness. The Stinger weapon round is made up of a missile round consisting of a Stinger missile within a launch tube mated to a separate gripstock. A battery/coolant unit (BCU) is inserted into the weapon round to provide prelaunch power to the system. All of the components, including the missile, separate gripstock, IFF antenna, and BCU, are necessary to have an operational weapon. The weapon is 60 inches long, and with BCU inserted, weighs 34.7 pounds. For IFF simulation capability, an IFF interrogator is connected by cable to the weapon. The Stinger tracking-head trainer (THT) a replica of the actual weapon, was used during the conduct of this experiment. The THT weighs about 40 pounds and simulates all the operational characteristics of the Stinger weapon. The additional 5 pounds results from the performance evaluation electronics mounted on the THT, which are not present on the actual weapon. The training given to teams during this test was performed using the same four Stinger THTs.

Environment

This test was conducted in the summer of 1987, under clear weather, daylight conditions. The mean visibility was 50 miles, and temperatures ranged between 80 and 100 degrees Fahrenheit. Windspeed ranged from 0 to 30 miles per hour. The test environment consisted of desert terrain, with no intermediate terrain masking of FW or RW targets. Targets were presented to the south of the four weapon positions.

Procedures

Four Stinger teams were tested simultaneously each day for three days. Of these twelve teams, three teams were tested redundantly on two separate days. For purposes of this experiment, only the data obtained from the first day of testing for each unique team were used. Hence, the data presented in

this report are based upon the first day of testing for nine teams.

Teams were alerted 10 seconds prior to target availability by a verbal alert message of "Red-Tight". This message established the Air Defense Warning Condition as "Red", meaning aircraft imminent and the Weapon Control Status as "Tight", meaning aircraft must be visually identified as "hostile" prior to engagement. Prior to the 10 second alert message, teams were oriented due north, away from the search sector. Upon issuance of the "Red-Tight" alert message, teams manned the weapon position in preparation for the target. After a trial ended, the teams were given the verbal message "Condition White" indicating that the air defense alert status had been changed from "Red" to "White", and that the teams should return to their positions facing away from the target area. The weapon was temporarily stored on a platform between trial presentations.

The aircraft interrogation process was simulated using an IFF Simulator, modified to emit only an "unknown" return. This was done to force teams to positively identify each aircraft as "friend" or "hostile" visually. No cues were given as to target azimuth or identity. All targets appeared within the 90 degree search sector which had to be visually searched without optical aiding to detect each target. The visual search process was allowed to vary among teams. Team chiefs used standard issue 7 x 50 power binoculars for the purpose of visual aircraft identification.

All teams were trained in and required to employ the following target engagement event sequence in accordance with doctrine (FM 44-18-1, 1984):

1. Both team members visually SEARCH the sector for aircraft.

2. Any team member who DETECTS the aircraft announces the word "Contact" along with a clock azimuth denoting its approach.

3. Gunner INTERROGATES the target (now in his sight reticle) by depressing the IFF button.

4. Team Chief visually IDENTIFIES aircraft (using binoculars) and announces it as "Hostile" or "Friendly".

5. Gunner, after sighting the target in the reticle and activating the system, ACQUIRES IR tone.

6. Team Chief commands either "ENGAGE" or "CEASE ENGAGEMENT".

7. Gunner LOCKS-ON to the target by holding down the uncage bar and receiving tone signal generated by the infrared seeker head.

8. Gunner FIRES or BREAKS-OFF from the current target engagement.

9. Both team members go back to SEARCH (#1 above).

The detection, identification, and command to engage or cease engagement events were time-coded and logged via manual keystroke entries made by data-collectors at each weapon position. The IFF interrogate, acquire, lock-on, and fire events were time-coded and logged via direct circuit taps on the four Stinger THTs. Each event was correlated to the range of the aircraft and the time elapsed after target availability.

"Target availability" was defined differently for the two types of aircraft. FW targets were declared available and the event timer was started when the aircraft began its attack run at a 20 km range. RW targets were declared available and the event timer was started when the helicopter popped-up from defilade and was available to be seen from the weapon positions (also called "line-of-sight").

RESULTS AND DISCUSSION

Two categories of data analyses were performed: descriptive and inferential statistics. The descriptive statistics provided an indication of the average performance across all teams for each sub-experiment. The inferential statistics (or, comparison tests) were employed to test the hypothesis of improved performance as a result of practice with feedback in RADES. The results of the comparison tests will be reported first.

Comparison Tests

Three levels of comparisons were performed. The first level compared pre-post scenarios presented in the morning, the second level compared pre-post scenarios presented in the afternoon, and the third level compared average single target responses in the morning with those from the afternoon. For levels one and two, the RW pretest targets were the large Soviet Mi-8 at 12 o'clock (azimuth) and the small US AH-1 at either 1 o'clock or 11 o'clock, respectively. The RW posttest targets were the large US CH-3 at 12 o'clock, and the small Soviet Mi-28 at either 11 o'clock or 1 o'clock, respectively. The FW pre-post target was a MiG-27 at 11:00 for the morning, and an Su-25 at 12:00 for the afternoon. Level three comparisons involved all single RW scenarios (5 through 10 versus 19 through 24) or all FW scenarios (1 through 4 versus 15 through 18).

The hypothesis being tested was that the engagement event responses would be better for the posttest measures than the pretest measures due to the training received. A one-tailed alpha was chosen and the significance level was set at 0.10. Pre- and post-treatment responses were compared to determine if performance differed using the sign test. A plus (+) was assigned to cases showing improvement with practice, and a minus (-) was assigned to cases showing a decrement in performance. Ties (no difference) were ignored. Tables 5 through 10 present the results of these comparisons.

Table 5
Pre- and Post-Treatment Comparisons of Rotary-Wing Event Times (Morning)

		PRE			POST			SIGN TEST	
VARIABLE	TARG	Mean	SD	N	Mean	SD	N	Cases (+,-)	Significance
TDET	1	5.0	1.5	9	2.4	1.0	8	8,0	p<.01
	2	30.5	5.4	8	24.0	1.2	8	7,0	p<.01
TID	BOTH	5.3	1.6	8	4.3	1.4	8	4,3	NS
TIFF	BOTH	7.2	3.8	6	8.0	6.1	4	1,3	NS
TACQ	BOTH	4.2	2.1	9	3.9	2.1	8	4,2	NS
TLOCK	BOTH	2.7	1.6	8	3.8	2.1	6	0,4	NS
TFIRE	BOTH	3.8	1.6	7	4.6	4.0	7	4,2	NS
THAND	BOTH	6.8	3.5	7	7.0	2.8	7	2,2	NS
TTOT	BOTH	11.0	3.6	7	11.3	1.6	7	3,2	NS

NOTE: NS = not significant
BOTH = mean response across both targets in the scenario

Table 6
Pre- and Post-Treatment Comparisons of Fixed-Wing Event Ranges and Times (Morning)

	PRE			POST			SIGN TEST	
VARIABLE	Mean	SD	N	Mean	SD	N	Cases (+,-)	Significance
RDET	6.7	1.9	9	6.1	2.1	8	3,4	NS
RID	4.2	1.4	9	3.7	1.0	8	3,5	NS
RIFF	5.6	1.7	7	4.9	1.1	6	1,5	NS
RACQ	4.1	1.2	9	4.0	1.1	7	3,4	NS
RLOCK	3.6	1.1	9	3.5	0.4	7	4,3	NS
RFIRE	3.3	0.6	9	3.3	0.5	7	2,6	NS
TID	10.2	3.7	8	11.7	5.8	8	3,4	NS
THAND	6.4	5.4	8	5.1	2.9	7	3,2	NS
TTOT	16.4	5.0	9	16.6	6.0	7	3,3	NS

NOTE: NS = not significant
Ranges in kilometers (full-scale); times in seconds

Table 7
Pre- and Post-Treatment Comparisons of Rotary-Wing Event Times (Afternoon)

		PRE			POST			SIGN TEST	
VARIABLE	TARG	Mean	SD	N	Mean	SD	N	Cases (+,-)	Significance
TDET	1	5.1	2.4	9	3.6	1.5	8	6,1	p<.10
	2	28.3	5.2	9	26.5	2.1	8	5,4	NS
TID	BOTH	6.8	1.2	9	4.3	2.0	9	8,0	p<.01
TIFF	BOTH	8.3	6.1	7	7.6	6.1	6	1,4	NS
TACQ	BOTH	5.3	3.2	9	3.6	3.0	9	6,3	NS
TLOCK	BOTH	4.4	2.2	8	3.7	1.0	8	5,2	NS
TFIRE	BOTH	4.0	2.9	8	3.6	2.9	8	4,1	NS
THAND	BOTH	5.2	1.3	8	6.4	2.0	8	2,6	NS
TTOT	BOTH	10.7	2.1	8	9.4	2.5	8	5,2	NS

NOTE: NS = not significant
BOTH = mean response across both targets in the scenario

Table 8
Pre- and Post-Treatment Comparisons of Fixed-Wing Event Ranges and Times (Afternoon)

	PRE			POST			SIGN TEST	
VARIABLE	Mean	SD	N	Mean	SD	N	Cases (+,-)	Significance
RDET	9.1	2.2	9	9.0	3.7	9	3,6	NS
RID	4.7	2.0	9	3.7	2.0	9	2,7	NS
RIFF	6.5	2.6	7	6.1	3.4	8	2,5	NS
RACQ	4.7	2.0	9	4.3	2.5	9	3,6	NS
RLOCK	4.3	2.2	8	3.1	1.8	9	1,7	NS*
RFIRE	3.4	1.1	9	2.3	1.0	8	1,7	NS*
TID	18.0	11.5	9	18.4	10.0	9	4,5	NS
THAND	9.6	6.1	9	8.0	6.8	8	3,5	NS
TTOT	27.6	9.8	9	28.0	10.4	8	4,4	NS

NOTE: NS = not significant
Ranges in kilometers (full-scale); times in seconds

* This difference was, however, statistically significant in the opposite direction ($p < .10$, two tailed test).

Table 9
Morning Versus Afternoon Comparisons of Single Rotary-Wing Event Times

	AM			PM			SIGN TEST	
VARIABLE	Mean	SD	N	Mean	SD	N	Cases (+,-)	Significance
TDET	5.2	1.3	9	5.1	Ø.8	9	2,2	NS
TID	6.6	2.1	9	6.5	1.5	9	2,4	NS
TIFF	4.1	2.9	7	4.5	1.6	8	2,4	NS
TACQ	4.9	1.5	9	5.8	2.4	9	2,3	NS
TLOCK	2.9	1.5	8	4.2	2.2	8	1,4	NS
TFIRE	3.8	2.5	9	4.3	2.7	9	3,5	NS
THAND	5.1	1.7	8	6.6	2.5	9	2,3	NS
TTOT	1Ø.Ø	1.8	9	11.9	3.4	9	Ø,5	NS*

NOTE: NS = not significant

* This difference was, however, statistically significant in the opposite direction (p < .1Ø, two tailed test).

Table 1Ø
Morning Versus Afternoon Comparisons of Single Fixed-Wing Event Ranges and Times

	AM			PM			SIGN TEST	
VARIABLE	Mean	SD	N	Mean	SD	N	Cases (+,-)	Significance
RDET	7.4	1.6	9	8.7	1.5	9	9,Ø	p<.Ø1
RID	3.7	1.1	9	4.2	1.Ø	9	7,2	p<.1Ø
RIFF	6.3	1.3	7	6.6	1.6	8	7,Ø	p<.Ø1
RACQ	4.1	1.9	9	4.7	2.3	9	7,2	p<.1Ø
RLOCK	3.9	1.7	9	3.5	1.8	9	4,5	NS
RFIRE	3.1	Ø.9	9	3.Ø	Ø.5	9	2,5	NS
TID	13.4	4.2	9	16.7	6.3	9	2,5	NS
TTOT	19.5	5.1	9	15.6	6.6	9	2,7	NS

NOTE: NS = not significant
Ranges in kilometers (full-scale); times in seconds

For the morning set of trials, posttest performance was superior to pretest performance for rotary-wing detection only. Both first and second RW targets were detected more quickly in the posttest (see Table 5). For FW, there was no evidence of improvement in the posttest (see Table 6).

The afternoon set of trials also showed improvement on RW responses. RW detection and identification times were shorter in the posttest trial (see Table 7). Afternoon FW responses did not improve for the posttest (see Table 8).

Tables 9 and 10 present the comparisons of morning versus afternoon trials for single RW and FW, respectively. There was no evidence of improvement for the RW event comparisons. However, improvement was found for FW events. FW detection, identification, interrogation, and acquisition all improved in the afternoon. Detection ranges improved by about 1.3 full-scale kilometers. It is believed that these improvements were a result of practice with feedback in RADES.

It should also be noted that first RW targets for the simultaneous RW scenarios (Sub-Experiment 4) were detected faster in the afternoon than in the morning (sign test, $p < .10$). This trend did not hold true for second and third targets, nor for sequential RW scenarios (Sub-Experiment 3).

The hypothesis under test was that Stinger teams would improve their performance as a result of practice with feedback in RADES. It was not expected that performance would deteriorate. Yet some examples of this reversal did appear. In Table 8 it can be seen that performance for both lock-on range and fire range decreased significantly from pretest to posttest (sign test, $p < .10$, 2-tailed). In Table 9 it can be seen that total engagement time increased significantly from pretest to posttest (sign test, $p < .10$, 2-tailed). All three examples of this reverse trend relate primarily to gunner tasks. All three reversals occurred during afternoon trials. Further, remember that the THTs weighed 40 pounds each, that they had to be lifted and shouldered dozens of times every day, and that the temperatures on the range approached 100 degrees Fahrenheit every afternoon. Thus, a plausible explanation is that these reverse effects resulted from fatigued gunners.

The results returned from these comparison tests were mixed. The RW results showed improvement in engagement performance from pretest to posttest for both morning and afternoon sets. This result was predicted and is explained simply as improvement with practice and feedback in RADES.

The FW results showed no such improvement from pretest to posttest in either morning or afternoon sets. This lack of a practice effect may have resulted from a lack of sufficient practice. There were only three FW trials between the pretest scenario and the posttest scenario for each set, whereas there were eight RW trials separating the pretest from the posttest scenario for each set. Perhaps no differences were found for the FW comparisons because the troops received too few practice trials between pretest and posttest for the effect to emerge.

The results of the morning versus afternoon comparisons were also mixed. Performance during the FW scenarios showed improvement from morning to afternoon. This is consistent with the practice explanation given above. Overall performance on RW scenarios did not improve from morning to afternoon for the single RW scenarios (Sub-Experiment 2), but did for the first target of the simultaneous RW scenarios (Sub-Experiment 4).

Descriptive and Summary Statistics

Summary performance measures for each treatment and target are provided in Tables 11 through 14. Descriptive statistics for this experiment were compiled across all teams, according to training treatment (sub-experiment) for each target. Descriptive statistics are given in Tables 15 through 18. These tables can be found at the end of this section.

Table 11 presents summary statistics for the Single Fixed-Wing test (Sub-Experiment 1). About one quarter of the aircraft were incorrectly identified, with the majority of the incorrect identifications being misidentifications of friendly aircraft. Hostile fixed-wing aircraft (i.e., MiG-27s and Su-25s) were identified correctly 94% of the time, and friendly fixed-wing aircraft (i.e., A-7s and A-10s) were identified correctly 44% of the time. Ninety percent of the aircraft perceived to be hostile were fired upon and 63% of hostile aircraft were destroyed. FW misses were most often attributable to target out of range (12%) or to loss of lock-on (10%). None of the FW hostiles were prevented from delivering ordnance. For friendly aircraft, 56% were incorrectly identified, 31% were engaged, and 17% were destroyed.

Table 12 provides summary statistics for the Single Rotary-Wing test (Sub-Experiment 2). Hostile rotary-wing aircraft (i.e., Mi-24s, Mi-28s, and Mi-8s) were correctly identified 88% of the time, and friendly rotary-wing aircraft (i.e., AH-1s, UH-1s and CH-3s) were correctly identified 72% of the time. Only 58% of engaged aircraft were destroyed. RW misses were most often attributable to target no longer available (22%) or to loss of lock-on (9%). The teams were 39% effective in preventing hostile ordnance release.

Table 13 provides summary statistics for the Double Sequential Rotary-Wing test (Sub-Experiment 3). All first target identifications were correct for both hostile and friendly aircraft. Identification performance for second targets was 76%. Most second target misidentifications were of friendly aircraft. The percentage of engaged aircraft destroyed dropped from two-thirds to one-half from first to second target engagements. Overall, 57% of the hostile targets would have released their ordnance.

Table 14 presents summary statistics for the Simultaneous Double and Triple Rotary-Wing test (Sub-Experiment 4). Only 15% (overall) of the hostile aircraft were misidentified. About 21% (overall) of the friendly aircraft were misidentified. Correct identification rate for the first target detected was 89%, while for second and third targets detected combined it was 79%. The first hostile target detected was destroyed at a rate of 48%, while the second hostile target detected was destroyed 83% of the time. Hostile ordnance release averaged about 50%.

Table 15 presents overall engagement event range descriptive statistics for Sub-Experiment 1, the Single Fixed-Wing test. Engagement event target ranges are in full-scale kilometers. Table 15 also provides the engagement event ranges separately for hostile and friendly fixed-wing targets. Mean detection ranges were at 8 kilometers, with identification occurring at about 4 kilometers. The period from detection to identification took about 15 seconds. The total engagement period from detection to fire took about 22 seconds. Range at target kill was greater than range at weapon fire because the majority of FW kills occurred while the target was outbound. This is also why there were no FW ordnance preventions.

Table 16 presents engagement efficiency descriptive statistics for Sub-Experiment 2, the Single Rotary-Wing test. Engagement times are also presented separately for hostile and friendly aircraft. The mean period from detection to identification was 6.5 seconds and the mean time between detection and fire was 11 seconds. Detection occurred about five seconds subsequent to line-of-sight. The time interval from target detection to target identification took over half the period between detection and fire. Time of target kills occurred at about 18 seconds after line-of-sight was established.

Table 17 presents engagement efficiency descriptive statistics for Sub-Experiment 3, the Sequential Double Rotary-Wing test. Target one and two engagement times were approximately equivalent. The time to identify took about half the engagement time subsequent to detection. The total engagement period from detection to fire took about 10.5 seconds.

Table 18 presents engagement efficiency descriptive statistics for Sub-Experiment 4, the Simultaneous Double and Triple Rotary-Wing test. For the first target detected, the mean period from detection to fire was 10.3 seconds. The interval between detection and identification was 5 seconds. For the second target detected, the mean period from detection to fire was 11.2 seconds. The interval between detection and identification was 5.7 seconds. For the third target, the mean period from detection to fire was 8.5 seconds. The interval between detection and identification was 3.7 seconds. However, fewer teams engaged the second and third targets. The majority of first target detections were of hostile aircraft, second targets were either friendly or hostile, and third targets were primarily friendly.

In summary, of the total engagement period (target availability through fire), the detection task took about a third of the time, the identification task took about a third of the time, and the gunner weapon actions took about a third of the time.

Table 11
Single Fixed-Wing -- Sub-Experiment 1 Summary Statistics

VARIABLE	%	N
Targets Detected	100	87/87
Targets Identified	98	85/87
Correct Identifications	74	63/85
Incorrect Identifications	26	22/85
Hostiles Correctly Identified	94	48/51
Friends Correctly Identified	44	15/34
Hostiles Engaged	90	47/52
Friends Engaged	31	11/35
Engaged Aircraft Destroyed	67	39/58
Hostile Aircraft Destroyed	63	33/52
Friendly Aircraft Destroyed	17	6/35
Hostiles Delivering Ordnance	100	52/52

Table 12
Single Rotary-Wing -- Sub-Experiment 2 Summary Statistics

VARIABLE	%	N
Targets Detected	95	103/108
Targets Identified	94	102/108
Correct Identifications	80	82/102
Incorrect Identifications	20	20/102
Hostiles Correctly Identified	88	46/52
Friends Correctly Identified	72	36/50
Hostiles Engaged	69	37/54
Friends Engaged	20	11/54
Engaged Aircraft Destroyed	58	28/48
Hostile Aircraft Destroyed	39	21/54
Friendly Aircraft Destroyed	13	7/54
Hostiles Delivering Ordnance	61	33/54

Table 13
Sequential Double Rotary-Wing -- Sub-Experiment 3 Summary Statistics

VARIABLE	Target 1 %	Target 1 N	Target 2 %	Target 2 N
Targets Detected	100	35/35	94	33/35
Targets Identified	94	33/35	94	33/35
Correct Identifications	100	33/33	76	25/33
Incorrect Identifications	0	0/33	24	8/33
Hostiles Correctly Identified	100	18/18	94	15/16
Friends Correctly Identified	100	15/15	59	10/17
Hostiles Engaged	68	13/19	83	15/18
Friends Engaged	0	0/16	33	6/18
Engaged Aircraft Destroyed	69	9/13	48	10/21
Hostile Aircraft Destroyed	47	9/19	50	9/18
Friendly Aircraft Destroyed	0	0/16	6	1/18
Hostiles Delivering Ordnance	63	12/19	50	9/18

Table 14
Simultaneous Double and Triple Rotary-Wing --
Sub-Experiment 4 Summary Statistics

VARIABLE	Target 1 %	Target 1 N	Target 2 %	Target 2 N	Target 3 %	Target 3 N
Targets Detected	100	36/36	92	33/36	61	11/18
Targets Identified	97	35/36	89	32/36	56	10/18
Correct Identifications	89	31/35	78	25/32	80	8/10
Incorrect Identifications	11	4/35	22	7/32	20	2/10
Hostiles Correctly Ident.	89	24/27	79	15/19	100	2/2
Friends Correctly Ident.	87	7/8	77	10/13	75	6/8
Hostiles Engaged	67	18/27	57	12/21	33	1/3
Friends Engaged	33	3/9	14	2/14	13	1/8
Engaged Aircraft Destroyed	76	16/21	79	11/14	50	1/2
Hostile Aircraft Destroyed	48	13/27	83	10/12	33	1/3
Friendly Aircraft Destroyed	33	3/9	50	1/2	0	0/8
Hostiles Delivering Ordnance	52	14/27	52	11/21	100	3/3

Table 15
Single Fixed-Wing Events --
Sub-Experiment 1 Descriptive Statistics

Event	N	Mean	Std Dev	Range	Min	Max
RDET	87	8.1	3.3	14.2	2.8	17.0
RID	85	4.1	2.2	10.0	1.2	11.2
RIFF	69	6.4	3.2	13.8	1.9	15.7
RACQ	74	4.8	3.0	12.9	1.3	14.2
RENG	85	3.7	1.9	9.7	1.2	10.9
RLOCK	65	4.0	2.4	12.4	1.2	13.6
RFIRE	58	3.0	1.2	5.7	1.0	6.7
RKILL	29	3.5	1.3	4.7	1.2	5.9
TID	83	15	10	37	2	39
THAND	56	7	6	24	1	25
TTOT	58	22	10	41	7	48

	Hostile Targets			Friendly Targets		
Event	N	Mean	Std Dev	N	Mean	Std Dev
RDET	52	7.8	3.0	35	8.6	3.8
RID	51	3.7	1.7	34	4.6	2.7
RIFF	42	5.6	2.3	27	7.8	3.9
RACQ	50	4.4	2.4	24	5.7	3.9
RENG	51	3.5	1.6	34	3.9	2.3
RLOCK	46	3.5	1.7	19	5.1	3.5
RFIRE	47	2.9	1.0	11	3.2	1.9
RKILL	26	3.4	1.4	3	4.3	0.4
TID	49	16	10	34	15	10
THAND	45	7	6	11	6	7
TTOT	47	23	10	11	19	10

NOTE: Ranges in kilometers; times in seconds

Table 16
Single Rotary-Wing Event Times (Seconds) --
Sub-Experiment 2 Descriptive Statistics

Event	N	Mean	Std Dev	Range	Min	Max
TDET	103	5.1	3.5	18	2	20
TID	102	6.5	3.6	20	1	21
TIFF	57	4.1	4.6	21	1	22
TACQ	74	5.2	3.2	17	0	17
TENG	100	1.1	1.5	11	0	11
TLOCK	54	3.5	2.2	12	1	13
TFIRE	46	3.9	2.6	10	1	11
TKILL	24	18.2	1.8	7	14	21
THAND	46	5.9	2.9	16	1	17
TTOT	48	11.0	3.5	19	4	23

	Hostile Targets			Friendly Targets		
Event	N	Mean	Std Dev	N	Mean	Std Dev
TDET	52	4.3	1.6	51	5.9	4.6
TID	52	6.2	3.3	50	6.9	3.9
TIFF	26	4.3	4.7	31	4.0	4.6
TACQ	47	5.5	3.4	27	4.6	2.8
TENG	51	0.8	0.6	49	1.5	1.9
TLOCK	39	3.6	2.4	15	3.2	1.9
TFIRE	35	4.1	2.8	11	3.3	1.7
TKILL	18	18.4	1.9	7	17.8	1.7
THAND	35	6.0	3.1	11	5.7	2.3
TTOT	37	11.2	3.5	11	10.6	3.5

Table 17
Sequential Double Rotary-Wing Event Times (Seconds) --
Sub-Experiment 3 Descriptive Statistics

Target 1

Event	N	Mean	Std Dev	Range	Min	Max
TDET	35	4.8	4.7	28	1	29
TID	33	4.8	2.0	6	3	9
TIFF	16	8.8	5.7	16	1	17
TACQ	22	4.3	3.7	15	0	15
TENG	33	1.1	1.1	5	0	5
TLOCK	16	3.2	1.7	6	1	7
TFIRE	13	3.9	2.7	10	1	11
THAND	13	6.2	2.9	10	2	12
TTOT	15	10.4	3.3	11	5	16

Target 2

Event	N	Mean	Std Dev	Range	Min	Max
TDET*	33	27.4	4.7	20	22	42
TID	33	5.6	3.2	10	2	12
TIFF	17	6.2	6.8	19	1	20
TACQ	29	4.0	3.2	15	0	15
TENG	33	0.8	0.7	8	0	8
TLOCK	21	4.0	2.5	10	1	11
TFIRE	21	3.9	3.0	10	1	11
THAND	20	6.1	2.5	10	2	12
TTOT	21	10.7	2.7	11	5	16

* TDET is measured in seconds from Target 1 availability. Hence, TDET for Target 2 is the accumulated time from Target 1 availability until the detection announcement for Target 2.

Table 18
Simultaneous Double & Triple Rotary-Wing Event Times (Seconds) -- Sub-Experiment 4 Descriptive Statistics

Target 1

Event	N	Mean	Std Dev	Range	Min	Max
TDET	36	6.1	6.5	32	21	53
TID	34	5.0	2.4	8	2	10
TIFF	13	6.3	4.8	13	1	14
TACQ	27	3.9	2.7	11	0	11
TENG	35	1.1	1.2	12	0	12
TLOCK	23	3.3	1.5	5	1	6
TFIRE	20	4.7	4.6	21	1	22
THAND	19	7.0	4.9	22	2	24
TTOT	21	10.3	6.0	29	3	32

Target 2

Event	N	Mean	Std Dev	Range	Min	Max
TDET*	33	20.1	6.9	30	11	41
TID	32	5.7	4.1	18	1	19
TIFF	17	3.4	5.4	21	1	22
TACQ	23	4.1	2.5	10	1	11
TENG	32	1.1	0.7	14	0	14
TLOCK	14	4.8	3.6	12	1	13
TFIRE	13	3.7	3.5	12	1	13
THAND	13	6.4	3.7	12	1	13
TTOT	14	11.2	3.8	11	7	18

Target 3

Event	N	Mean	Std Dev	Range	Min	Max
TDET*	11	30.2	7.1	22	20	42
TID	10	3.7	2.4	8	1	9
TIFF	6	4.8	3.1	8	1	9
TACQ	5	4.6	3.2	8	1	9
TENG	10	2.6	4.5	12	0	12
TLOCK	3	6.0	2.0	4	4	8
TFIRE	2	2.0	0	0	2	2
THAND	1	11.0	0	0	11	11
TTOT	2	8.5	9.2	13	2	15

* TDET is measured in seconds from Target 1 availability. Hence, TDET for subsequent targets (2 and 3) represents the accumulated time from Target 1 availability.

CONCLUSIONS

The primary purpose of this research effort was to exercise the new RADES multiple fire-unit configuration in the collection of performance data. The system operated successfully. RADES was able to collect the required data from four teams per day for three days. With the previous single-fire-unit system, a comparable amount of data would have required twelve days. Thus, the new system makes more efficient use of research time. Also, since all fire units engaged the same aircraft in parallel on every trial, the new system makes more efficient use of stimulus-presentation resources (e.g., aircraft, pilot personnel, aircraft maintenance, radar transponders, etc.). Further, all four data-collection stations were operational during all test days.

The second reason for this effort was to determine if an improvement in performance for Stinger teams would result from practice and feedback in RADES. These results were mixed. Teams improved from pretest to posttest on the rotary-wing scenarios, within the morning and within the afternoon sets, but not on the fixed-wing scenarios. However, teams improved from the morning set to the afternoon set on the fixed-wing scenarios. Teams did not show improvement from morning to afternoon on the single target rotary-wing scenarios, but did show improvement on the first target in multiple, simultaneous rotary-wing scenarios.

The RADES practice effect has been observed on previous occasions. One prior RADES comparison experiment using similar RW scenarios and equivalent conditions revealed a large practice effect for Stinger teams recently graduated from advanced individual training (Barber, Drewfs, & Lockhart, 1987). A baseline performance evaluation test also revealed a positive practice effect for novice Redeye teams during simulated engagements of rotary-wing aircraft (Barber, 1987).

The third purpose of this research was to provide training to Stinger teams stationed at Fort Bliss. RADES was able to provide a minimum of thirty training trials to four teams per day for three days. Both the Stinger teams themselves and their Platoon Leader expressed appreciation for the training and volunteered their support for additional training in the future.

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APPENDIX

The RADES Simulation Facility

In order to evaluate accurately how well SHORAD (Short Range Air Defense) and FAADS (Forward Area Air Defense Systems) crews react to hostile and friendly aircraft flying tactical maneuvers in today's modern battlefield, the ARI Fort Bliss Field Unit has designed, developed, validated, and utilized RADES as a subscale facility which realistically simulates critical aspects of the forward area engagement environment. RADES exploits state-of-the-art simulation and measurement technology. It provides flying fixed-wing (FW) and pop-up rotary-wing (RW) US and Soviet targets at known distances against up to five real, instrumented, weapon systems and obtains accurate detailed results of weapon system, gunner, and crew actions for each engagement.

RADES is located at Condron Field, White Sands Missile Range, New Mexico. This desert area contains mountains 10 km to the west and 60 km to the south. Visibility is usually in excess of 60 km. Skies are usually clear.

On a given test day, up to five SHORAD or FAADS weapon systems are moved into their respective weapon stations in the test area. Each weapon station consists of a crew or team and their weapon, a "universal weapon interface", a "lap-top" microprocessor, and a human data collector. Also at each weapon station are loudspeakers playing battlefield sounds. These sounds are designed to mask irrelevant audio cues during the engagement process. The interface collects such weapon-specific gunner actions as IFF interrogation, acquisition, lock-on, and fire. The data collector, using the lap-top keyboard, inputs crew verbal responses such as detection, visual identification, and the command to engage or to cease engagement. The weapon stations are connected, via cable, to RADES control in a multi-drop communications network.

At the start of the exercise, the soldiers, having already received their operations order for the day, are placed on alert with orders to react to any situation "as if it were the real thing". Crew or team members search the sky for aircraft. Detected aircraft are handed-off to the gunner for tracking and the leader for visual identification. After an aircraft has been identified as hostile, the leader issues the command to engage and the gunner completes the engagement process. If the gunner's actions are correct, the computer allows for missile flight time and, if the target is in range at intercept, assigns a "kill". The data collectors notify each crew or team whether they obtained a "kill".

The non-flying helicopters include one-fifth scale models of the US UH-1 Iroquois, AH-1 Cobra, CH-3 Jolly Green Giant, UH-60 Blackhawk, and AH-64 Apache and the Soviet Mi-24 Hind-D, Mi-8 Hip, and Mi-28 Havoc. The helicopters are mounted on stands, located strategically throughout the test area, and pop-up, pneumatically, under computer control from behind sand dunes at scenario-scripted distances in front of the weapon systems.

The FW targets include one-seventh scale models of the US A-7 Corsair II, A-10 Thunderbolt II, F-16 Fighting Falcon, and F-111 and the Soviet MiG-23/27 Flogger, Su-7 Fitter, Su-17/20/22 Fitter, Su-24 Fencer, and Su-25 Frogfoot. Because the RADES aircraft are subscale, the rest of the test activities can be scaled down in size. Past studies have shown that spotters usually detect aircraft at distances ranging out to 14 kilometers. Scaling this down to one-seventh means RADES only requires a two kilometer square of airspace for its testing.

All RADES aircraft are evaluated for target shape fidelity before they are certified for use in experiments. The certification procedure for the FW aircraft recognizes the trade-off between exact duplication of a target's physical dimensions, and the aerodynamic requirements that a target not only fly, but also simulate tactical maneuvers. RADES personnel visually examine prototype FW models when they arrive from the subcontractor and compare them to pictures of the actual aircraft published in FM 44-30 ("Visual Aircraft Recognition"). A model's silhouette must conform to that of the full-scale aircraft or it is rejected.

Prototype RW models are also visually examined and compared to the published pictures of the full-scale aircraft in FM 44-30. In addition, each RW model's primary dimensions (length of fuselage, width of fuselage, height of fuselage, and length of wing, where appropriate) are measured and compared to these (scaled) dimensions for the full-size aircraft. Dimensions of actual aircraft are published in Army and Air Force Technical Manuals and Jane's All the World's Aircraft (Taylor, 1984). All current RW models meet the criterion of being within plus or minus five percent of the actual aircraft on all measured (scaled) dimensions.

The FW, radio-controlled, propeller-driven models are stored, repaired, and readied for flight at Condron Field. On each test day, they are transported into the desert out of sight of weapon system personnel, launched from a catapult launcher, and flown by expert radio-controlled aircraft pilots into the test range in the direction of the weapon systems. The pilots fly scenario-driven flight paths. The flight paths are displayed graphically inside the target control van and the pilots are guided by voice radio.

In RADES, FW targets are detected, located in X and Y coordinates, tracked, and ranged using a radar system, an automated radar plotting device, and an automated software track filter running on the Flight Tracking Component (FTC) microprocessor.

RADES uses a marine radar adapted for use in the system by Science Applications International Corporation and Radar Devices, Inc. RADES flying targets carry radar transponders which return exactly that signal the radar is looking for. When the radar receives a transponder-returned signal, it outputs it to the automated radar plotting device, which in turn outputs range in device-specific units of measurement, and target azimuth to the FTC computer.

The FTC computer converts the range value to RADES coordinates, filters out spurious return signals, and calculates the target's position. When the target's position has been calculated, the FTC computer forms a target position and status message and outputs it to the control station microprocessor. The control station computer, in turn, broadcasts the message to the respective weapon station graphics screens. Flying target position updates, transmitted from the control station computer to the weapon station lap-tops, are used by weapon station software to calculate the local weapon-to-target range at which weapon and crew events occur.

Weapon stations are accurate in capturing time-of-event data to the nearest 250 milliseconds. This is contrasted with the track updates which occur every 2 seconds. To fill in the missing track positions and to assign correct target position at time-of-event occurrence, the weapon station software linearly interpolates intermediate track positions. Thus, an accurate estimate of target position at time-of-event occurrence for RADES training and test purposes is achieved.

Graphic and tabular feedback on the times and ranges of events, on the correctness of aircraft identifications, and the effects of engagement can be returned immediately upon the end of each scenario. Data collectors, in cooperation with unit leaders, interpret the RADES feedback screens against experimentally validated teaching points and provide end-of-trial corrective instruction to the crew or team members at the weapon stations. At the control station, hardcopy outputs of these graphics and tabular feedback displays can be printed for any or all RADES weapon stations currently being exercised.